

# Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications

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Project ID # bat355

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# Program Overview

## Timeline

- Project Start Date: Feb. 2017
- Project End Date: Sept. 2020
- Percent complete : 100%

## Budget

- \$5.9M
- 50%/50% USABC/Farasis
- Subcontractors
- LBNL \$300K
- ANL \$400K

## Barriers

- Achieving high energy density with stable chemistry to meet cycle life and calendar life goals.
- Meeting the cost target of ~ \$0.10/Wh
- Manufacturing processes compatible with new materials

## Partners

- BASF
- 3M/OneD material/Shin-Etsu/XG Science
- Argonne National Lab
- Lawrence Berkley Lab
- Solvay/ Daikin
- Entek/Celgrad



# Relevance/Project Objectives

- Project Objective

- Develop a EV cell technology capable of providing 280 Wh/kg after 1000 cycles at a cost target of \$0.10/Wh.
- To achieve this the BOL cell energy density target will be ~ 330Wh/Kg.

CELL LEVEL ATTRIBUTES	Units	Baseline (BOL)	Final Cells (BOL)- 2017	Final Cells (BOL)-2018
Cell Capacity (C/3 Rate discharge)	Ah	28.5	64	87
Cell Volume (without terminals/tabs)	L	0.222	0.24	0.3984
Cell Mass	kg	0.49	0.58	0.947
Vmin continuous, Vmax continuous (0 and 100% SOC)	V,V	3.0, 4.2	2.5, 4.5	2.75, 4.2
Vmin pulse, Vmax pulse (10 sec pulses)	V,V	2.5, 4.25	2.4, 4.5	2.5, 4.25
Vnominal (Wh/Ah)	V	3.68	3.55	3.6
Energy Density (volumetric)	Wh/L	470	947	786
Specific Energy	Wh/kg	215	392	331
Power Density (10 sec. HPPC power), 50% SOC	W/L	5440	2910	1778
Specific Power (10 sec. HPPC power), 50% SOC	W/kg	2460	1204	748
Target Cost / unit (>10 million cells/annum rate)	\$	16 - 19	25 - 31	25 - 31
Cell format (cylindrical/prismatic)		Pouch	Pouch	Pouch
Cell dimensions: (height x width x thickness)	mm	230 x 160 x 6	230 x 160 x 6	294.4 x 100.4 x 14



# Relevance/Project Objectives

- Project Technical Target

- Year 1: Baseline deliverable (220Wh/Kg)
- Year 2: Gen1 Deliverable (300Wh/Kg)
- Year 4: Gen2 Deliverable (330Wh/Kg)

- Cell Component R&D

- Comparative evaluation of positive and negative electrode active material blends.
- Optimization of negative electrode formulation for maximum energy density and cycle life.
- Investigate effect of Si incorporation on negative electrode conductivity and mechanical stability relative to graphite-only active material electrodes.
- Additive package development to optimize SEI formation on Si anodes.
- Stability of Ni rich Cathode

- Risk

- There are multiple interacting failure mechanisms at the materials and cell level that are barriers to achieving the system level battery performance goals.
- Calendar life of the Gen1 and cycle life for Gen 2 Cells
- Safety and cost targets



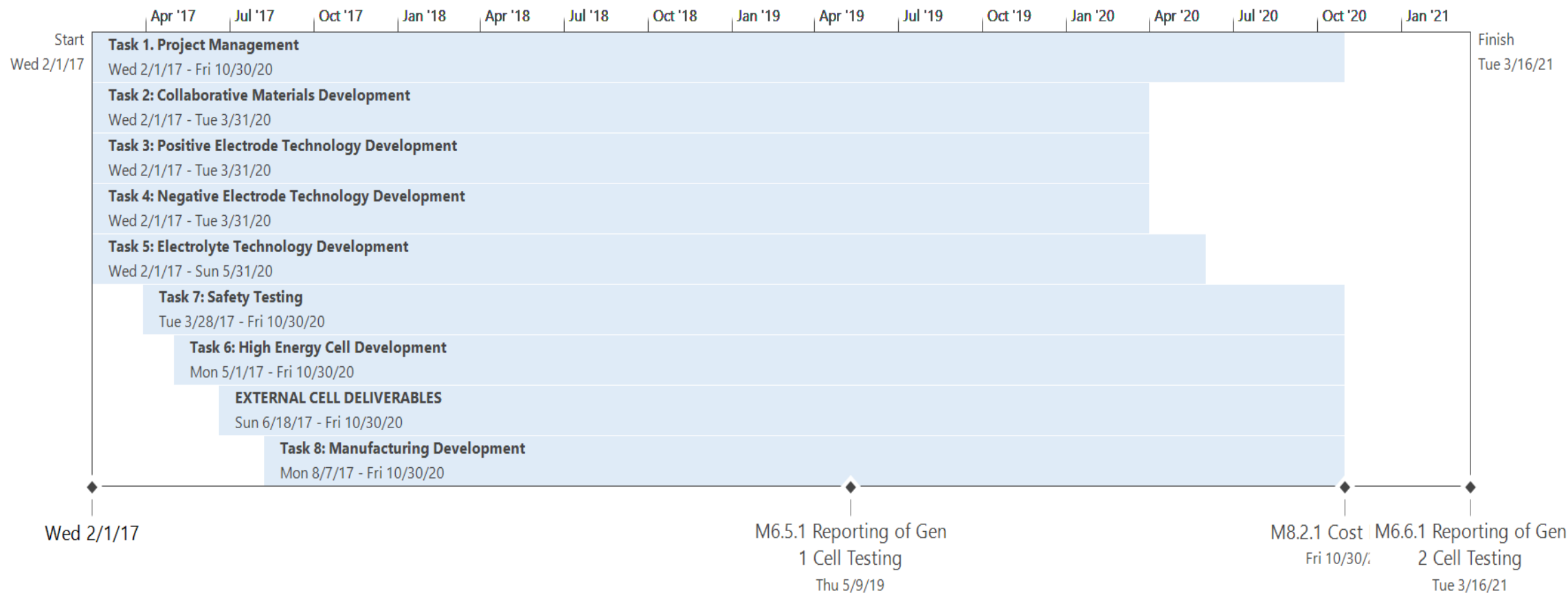
# Project Milestones

- The key Milestones are associated with demonstrating progress towards the goals of the project.

Milestone Summary Table						
Task Number	Task Title	Milestone or Go/No-Go Decision Point	Milestone Number	Milestone Description (Go/No-Go Decision Criteria)	Planned Completion Dates	% Completed
3.3	Positive Electrode Developmental Cell Build	Milestone	M3.3.1	Production of pouch cells representing multiple positive electrode design variants	July, 2017	100%
4.3	Negative Electrode Developmental Cell Build	Milestone	M4.3.1	Production of pouch cells representing multiple negative electrode design variants	July, 2017	100%
6.2	Ongoing Cell Development	Go/No-go	G6.2.1	Demonstration of High-Energy Cells exceeding 300 Wh/kg after RPT2	April, 2018	100%
6.5	Generation 1 Cell Testing	Milestone	M6.5.1	Completed reporting of performance and safety testing results for Generation 1 cells	January, 2019	100%
8.2	Cost Model Development	Milestone	M8.2.1	Submission of detailed cost model based on new materials and processes used in Generation 2 cells.	October, 2020	100%
6.7	Generation 2 Cell Testing	Milestone	M6.7.1	Completed reporting of performance and safety testing results for Generation 2 cells	October, 2020	100%



# Milestone Timing





# Technology Approach

- Development focused on addressing key current barriers to achieving high capacity, long cycle life and safer Li-ion cells

- **Electrode Chemistry:**

- Stabilized Ni-rich Cathode: Capacity ~ 220-240 mAh/g
- Silicon Composites: Capacity ~ 400-600 mAh/g

**Contributors:** Argonne National Laboratory, OneD, 3M, Shin-Etsu XG Sciences, BASF, Nanoscale Components

- **Electrolyte Formulation:**

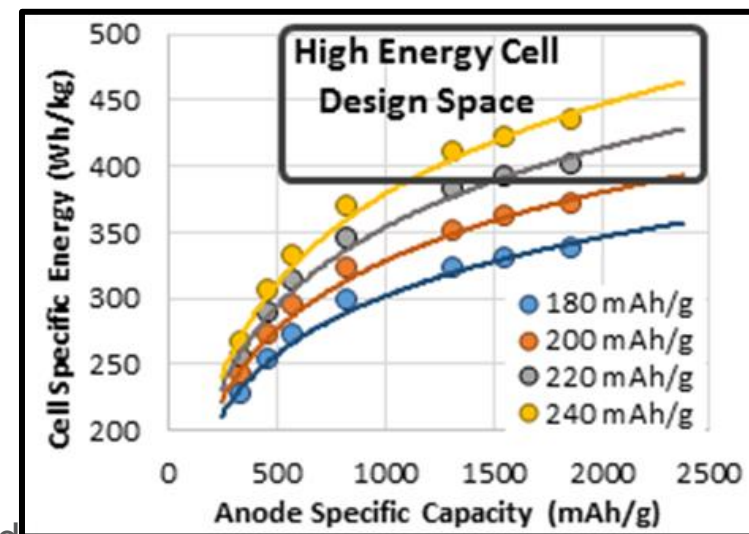
- Fluorinated solvents
- Stabilizing additives/salts.

**Contributors:** Solvay, Daikin, 3M, BASF

- **Electrodes and Cell:**

- Optimized, high density, composite active material formulations
- Low reactivity conductive additives
- Advanced binder formulations
- Advanced separators: Coatings, high voltage stability

**Contributors:** Lawrence Berkeley National Laboratory, Entek, Celgard





# Strategy - Development Plan

## Cell materials development

New materials sourcing and characterization  
New materials improvement, synthesis, development (ANL, LBNL)  
**Form factor: Coin Cells**  
Metrics: Capacity, rate, stability

### Task Status: Colors

Blue	Done
Green	Active with some delay
Red	Stopped
Black	Non-Active

## Positive electrode

**C1: ~ 11 Materials Variations (~ 300 Wh/Kg)**  
**C2: ~ 3 Materials Variations (shift to 400Wh/kg)**  
**C3 : ~ 2 Materials Variation ( Target ~ 330Wh/Kg)**  
**Form Factor: Small Full cells (SLP - <2Ah), fixed anode, electrolyte, energy density**  
Metrics: Capacity, rate, cycling, safety

## Negative electrode

**A1: ~ 4 Materials Variations ( ~ 300Wh/Kg)**  
**A2: ~ 4 Materials Composite Variations ( shift to 400Wh/Kg)**  
**A3: ~ 3 Materials Variations ( Target ~ 330Wh/Kg)**  
**Form Factor: Small Full cells (SLP - <2Ah), fixed anode, electrolyte, energy density**  
Metrics: Capacity, rate, cycling, safety

## Electrolyte

**E1: ~ 10 Materials Variations (~ 300 Wh/Kg)**  
**E2: ~ 5 Materials Variations (~ 320 Wh/Kg)**  
**E3 : ~ 5 Materials Variations (~ 330 Wh/Kg)**  
**Form Factor: 18650, <2Ah pouch, single cell design**  
Metrics: Capacity, rate, cycling, calendar life, safety

## Cell

**DOE1: ~ C1 & A1 ( Optimized formulation for 3 C1 & 2 A1 with 5 E1)**  
**DOE2: ~ C2 & A2 ( Optimized formulation for 2 C1 & 2 A1 with 5 E1)**  
**DOE3: ~ 7 Materials Variations**  
**Form Factor: Full cells, fixed anode, electrolyte, energy density**  
Metrics: Capacity, rate, cycling, safety

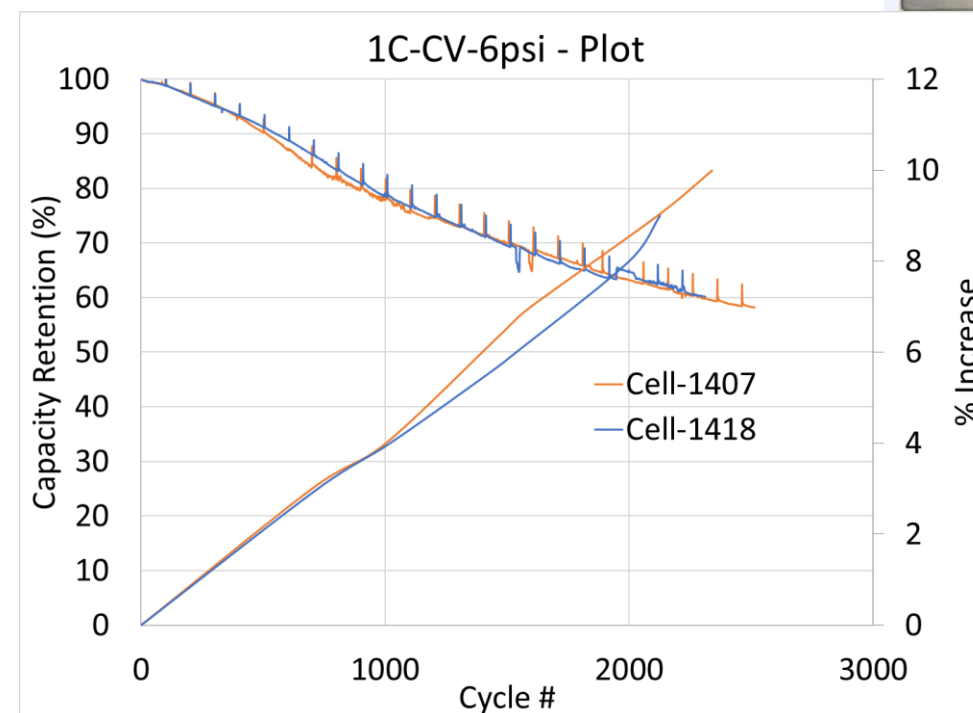
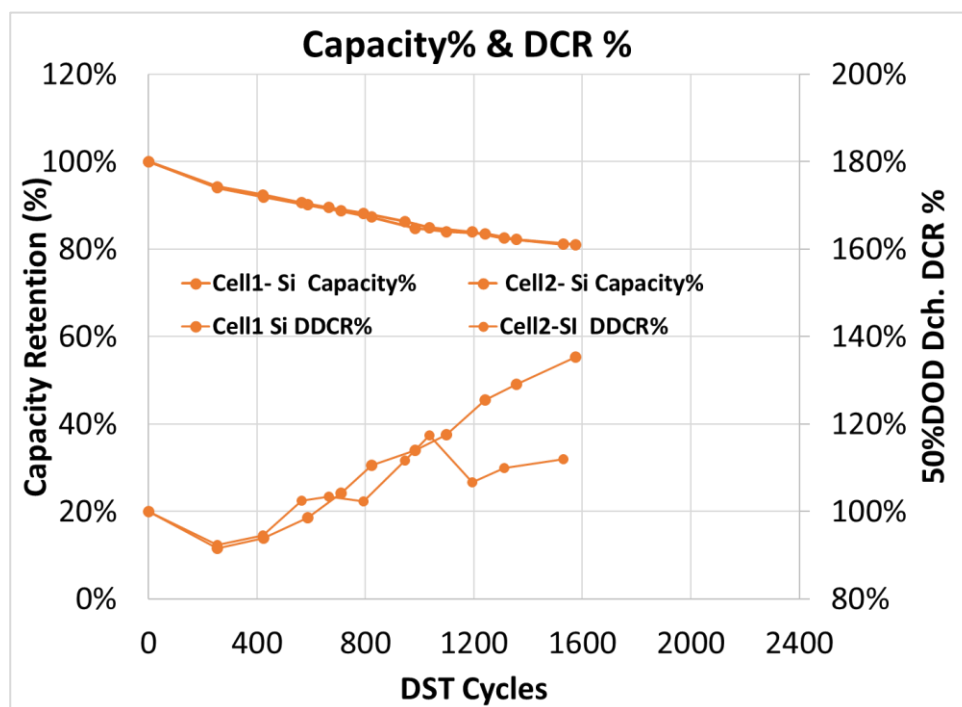
**Deliverables:**  
Baseline: Baseline (30Ah) NCM/Graphite  
Gen1: Gen 1 Cells (40Ah) Chemistry from DOE 1  
**Gen 2: Gen 2 Cells (87 Ah) Chemistry from DOE3**



# Technical Accomplishments

## Gen1 Delivered to National Labs: Test Summary

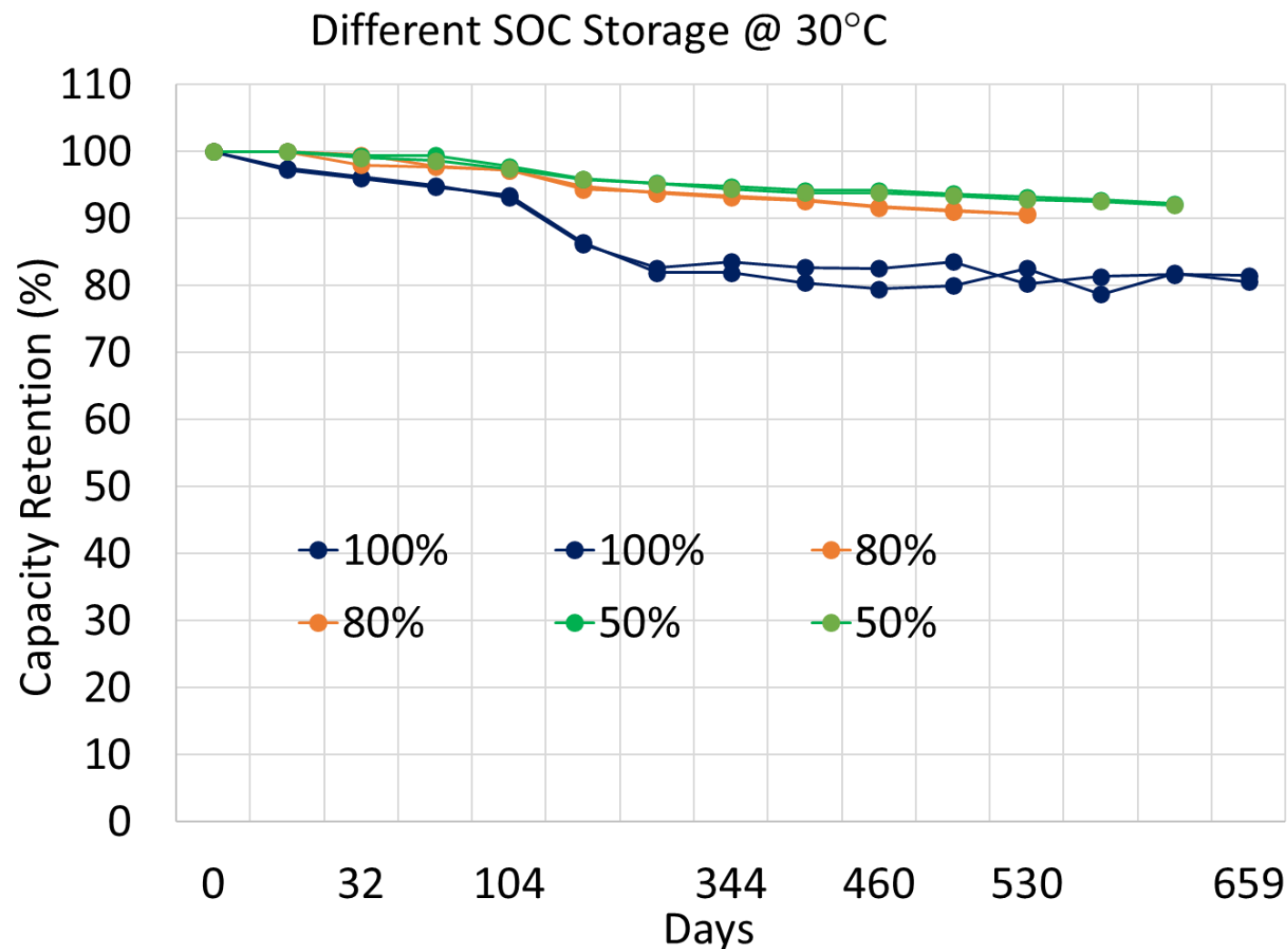
- Dynamic Stress Testing (DST) : Si/C composite with Ni rich NCM @ 30°C
- Cycle life: 1C/1C CV C/20
- Capacity of Cell 40 Ah with targeted specific energy of 310Wh/Kg for 80Ah Cell
- Cycle per RPT is 160-170
- DCIR : 50%DOD DDCR





# Technical Accomplishments

## Gen1 Delivered to National Labs: Calendar Life





# Technical Accomplishments

## Gen2 Delivered to National Labs: Cell Specifications

Cell Configuration		
Nominal Capacity	[Ah]	82
Nominal Voltage	[V]	3.6
Cycle Life (to 80% capacity)	[cycles]	>1000
Energy Density - Gravimetric	[Wh/kg]	~327*
Energy Density - Volumetric	[Wh/L]	~804 (USABC calculation)
Operating Voltage Vmax	[V]	4.2
Operating Voltage Vmin	[V]	2.5
Temperature Operating Range	[°C]	-20 to 55
Length	[mm]	294.4
Width	[mm]	103.9
Thickness	[mm]	13.5
DCIR, 50%SOC, 30s, 3C	[mOhms]	1.57
DCIR, 50%SOC, 10s, 1C	[mOhms]	1.1

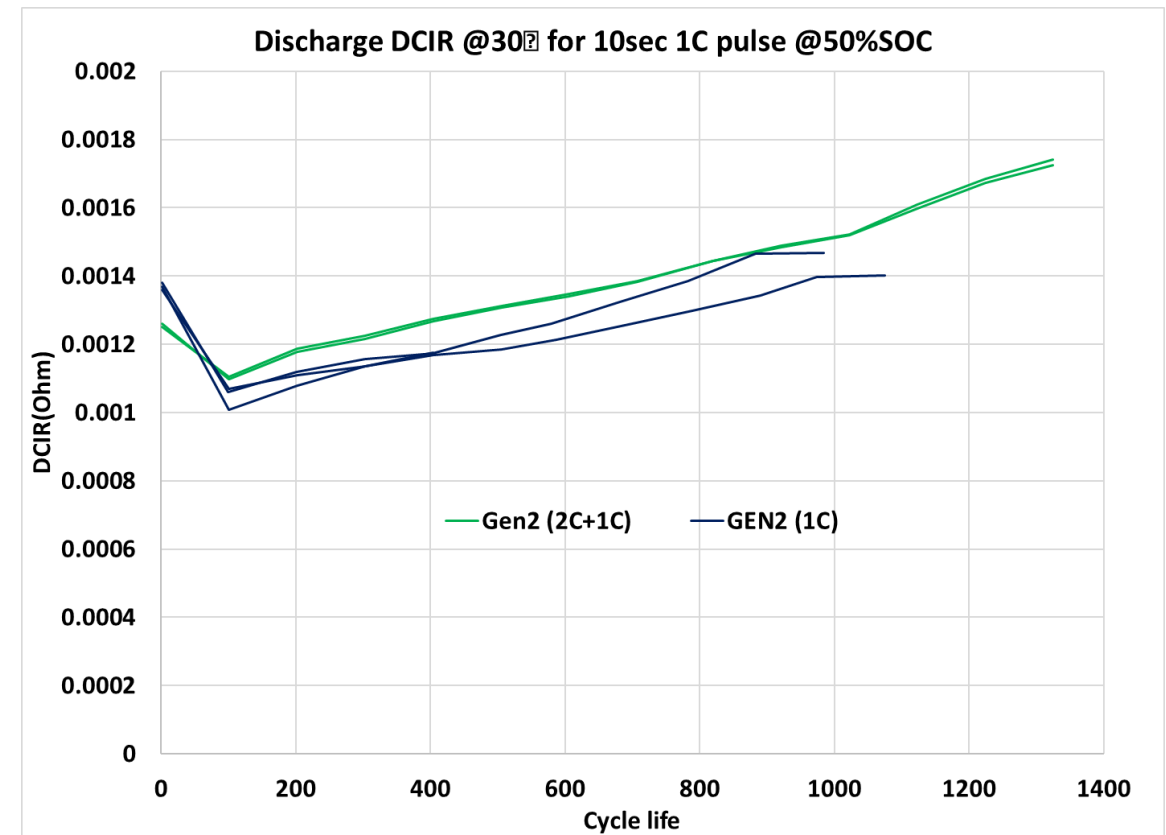
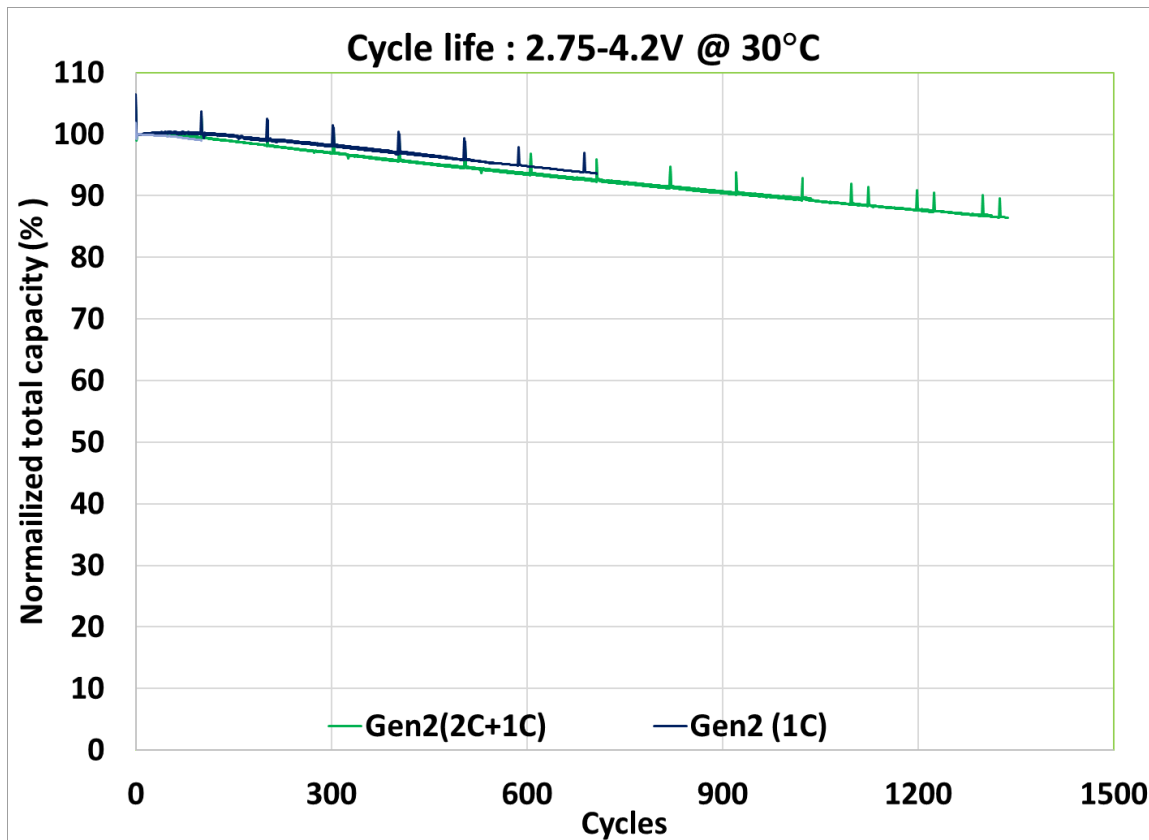
\* Gravimetric Energy Density (2.5 - 4.25V) = 335Wh/Kg



# Technical Accomplishments

## Gen2 Delivered to National Labs: Test Summary

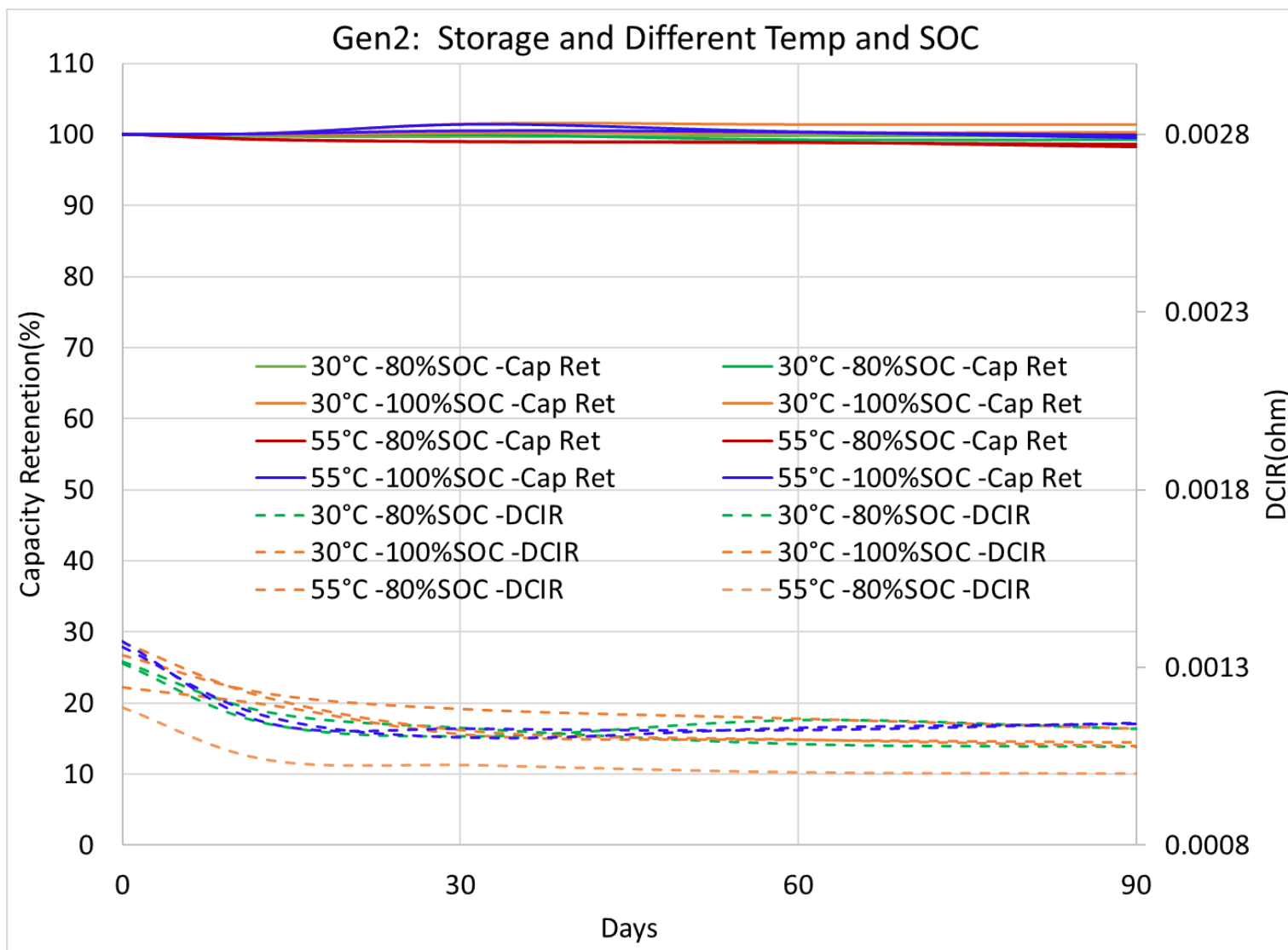
- Cycle life: 1C/1C CV C/20 and 1C/2C CV C/20
- Cycle per RPT is 160-170
- DCIR : 50%DOD DDCR





# Technical Accomplishments

## Gen2 Delivered to National Labs: Calendar Life





# Technical Accomplishments

## Summary Cell Development: Gen1 & Gen2

- **Gen 1 (300Wh/Kg)**

- Delivered to National Labs
- Tested internally
- Test data of National lab is comparable to the internal data
- Work is going on further improving the calendar life of the cells

- **Gen2 (330Wh/Kg)**

- **Cell design optimization**

- Delivered to National Labs
- Tested internally
- Test data of National lab is comparable to the internal data
- Cost analysis is done and reported in the closing report. USABC target achieved.



## Responses to Previous Year Reviewers' Comments

**Comment:** "The technology approach has been carried out by addressing key current barriers to achieving high capacity, long life cycle, and safety thoroughly".

**Response:** All the comments from the reviewer is positive about the management of the program, cell development as well as the funding of the project

**Comment:** "For this complicated problem, the team plans to look at cathode materials from seven different suppliers and electrolytes from three suppliers and investigate electrode formulations and cell designs." The reviewer indicated that the team does not explain how it plans to arrive at a final chemistry and a final cell design.

**Response:** During the quarterly review and reports, Farasis shows how we arrived at the final cell design

**Comment:** "Reviewer showed concern about volumetric energy density and swelling of the Si"

**Response:** We have done an extensive experiment on Gen2 cell in a fixed volume and generated the data for the pressure as well as cell swelling to design the module. During the poster presentation, I can explain the experiment in detail as Farasis is planning this cell to go under production in the next 2-3 year. The volumetric energy density of the cell is 806Wh/L whereas the target was 750Wh/L .



## Responses to Previous Year Reviewers' Comments

**Comment:** “The project has been following a fairly comprehensive work plan with a large test matrix of anode material, cathode material, electrolytes, additives, and even binders in pursuit of the Gen 2 goal early in 2021. Although comprehensive, it looks very much like trial-and-error”

**Response:** We have decided on the material based on their properties, commercialization and process capability. The binder, electrolyte and additives are decided based on the properties of the selected anode and cathode material. The program target was developed to bring this cell in SOP by 2023-24. In the quarterly review meeting and reports, Farasis have shown the reason behind the DOE and the material selection criteria.

**Comment:** “There is no cost assessment for making the cells in pilot-plant scale. Cost saving is one of the major objectives and the project is close to completion”

**Response:** Farasis submitted a detailed cost analysis report in the closing report. The extensive DOE is done to make sure that we have 2-3 competing material where we can negotiate about the cost. We can achieve the USABC program target and reported it in the program closing report.